surgical techniques. This also marked the beginning of laboratory research that focused on the host response to the foreign body. Since then, multiple human and animal studies have identified the host-tissue response as it relates to the placement of different types of mesh in different anatomic locations [11, 12] including many publications on the human tissue response to both synthetic and biological mesh used in the setting of abdominal hernia repair [13, 14].

Vaginal mesh may be excised after midurethral sling placement for different indications, most frequently for mesh exposure and obstructive voiding dysfunction with little known about the underlying histological explanation for these indications. Therefore, the aim of this study was to compare the histological characteristics of pathological specimens of excised midurethral sling mesh and surrounding vaginal tissue in patients who presented preoperatively with pain and/or exposure of mesh to patients who underwent mesh excision for voiding dysfunction without pain or erosion. We hypothesized that the histopathological findings would be different between these two groups, with more inflammation in those with pain and/or mesh exposure.

## Materials and methods

This was a retrospective chart review of women who underwent excision of midurethral sling mesh at a tertiary care center from 1 January 2008 through 1 January 2013. Institutional Review Board approval was obtained for this study. Patients were identified by their Current Procedural Terminology (CPT) code (57287) for removal or revision of sling for stress urinary incontinence. Subjects with incomplete documentation or absent pathological specimens were excluded. Once subjects were identified, the healthcare systemwide electronic medical record was queried for patient demographics and pre- and intraoperative data. Operative reports of the index surgery were reviewed if available. Data specific to the index surgery included type of mesh placed, date of surgery, and concomitant procedures. Previous treatment (physical therapy, vaginal estrogen, office-based excision, urethral dilation, and/or pharmacological intervention with anticholinergics) prior to operative mesh excision was also recorded.

Three separate groups were identified based on the indication for midurethral mesh excision: (1) voiding dysfunction without pain or exposure (control group), (2) pain and/or mesh exposure, and (3) voiding dysfunction with pain and/or mesh exposure. The original pathological specimens were rereviewed by a single pathologist blinded to the indication for excision as well as the previous pathology report. Degree of inflammation and fibrosis were recorded on a 4-point scale (range 0–3) developed specifically to compare histological differences at our institution (Table 1). The presence or absence of giant cell reaction was also recorded.

**Table 1** Histological grading system

| Chronic inflammation | |
|---|---|
| None (0) | Absent inflammation |
| Mild (1) | Sparse chronic inflammatory infiltrate, confined to areas of giant cell reaction if present |
| Moderate (2) | Moderate chronic inflammatory infiltrate in areas of giant cell reaction and involving adjacent connective tissue |
| Marked (3) | Marked inflammatory infiltrate in areas of giant cell reaction and prominently involving connective tissue; any germinal center formation |
| Fibrosis | |
| None (0) | Absent fibrosis |
| Mild (1) | Predominantly loose connective tissue with focal fibrosis |
| Moderate (2) | Focal dense fibrosis |
| Marked (3) | Dense fibrosis with formation of fibrous nodule/plaque |

Descriptive statistics were reported as *n*/*N* (%) with 95 % confidence intervals for categorical variables and as mean ±SD and median (range) for all continuous variables. Categorical variables were compared using the chi-square statistic and associations between outcomes were measured using a Fisher's exact test and Pearson's correlation coefficient. Comparisons of outcomes were performed using analysis of variance (ANOVA) for parametric continuous outcomes and Kruskal-Wallis for nonparametric continuous outcomes. For statistically significant results, pairwise comparisons were evaluated with Tukey analysis to identify the differences between the groups. All tests were considered significant at a 0.05 level. JMP 10.0 (SAS, Cary, NC, USA) was used for all statistical analyses.

## Results

A total of 191 subjects were identified by our CPT search criteria and 130 subjects of these met inclusion criteria. Mean age was 53.1 years (SD 11.3), average body mass index (BMI) was 29.7 (SD 6.9), and 28.5 % of subjects were identified as current tobacco users at the time of mesh excision. Demographic data did not differ among the three groups (Table 2). The use of conservative measures prior to sling incision was identified in 43.8 % of subjects, with office-based excision having been performed in 31.6 % (18/56), a trial of vaginal estrogen in 36.8 % (21/56), and a trial of anticholinergic medications for overactive bladder in 36.8 % (21/56) of subjects. Of the subjects, 60 (45.4 %) underwent mesh excision for voiding dysfunction, 21 (16.2 %) underwent excision for both pain/exposure and voiding dysfunction, and the remaining 49 (37.7 %) underwent surgical excision for both pain/exposure and voiding dysfunction. The histological data is shown in

**Table 2** Demographics of patients who underwent midurethral sling excision

| $N=130$ | Voiding dysfunction ($N=60$) | Pain/mesh exposure ($N=21$) | Voiding dysfunction and pain/mesh exposure ($N=49$) | $p$ value |
|---|---|---|---|---|
| Mean age (SD) | 54.8 (10.8) | 50.2 (8.1) | 52.2 (11.8) | 0.2 |
| Mean BMI (SD) | 30.0 (7.8) | 30.8 (5.6) | 29.1 (6.3) | 0.6 |
| Median parity (range) | 2 (0–6) | 2 (0–7) | 2 (0–6) | 0.6 |
| Diabetes mellitus (%) | 7.14 | 9.5 | 2.0 | 0.4 |
| Tobacco history (%) | | | | 0.8 |
| Current | 30.0 | 19.0 | 30.6 | |
| Past | 21.7 | 42.9 | 18.4 | |
| Never | 48.3 | 52.4 | 51.0 | |
| Chronic steroid use (%) | 1.7 | 0 | 0 | 0.6 |

Table 3. The most common finding in all groups was mild inflammation (found in 53.9 % of specimens) and only 9.2 % of specimens showed no inflammation. Moderate or marked inflammation was noted in 48 (36.9 %) specimens. Specimens in the voiding dysfunction only group were found to have higher amounts of moderate inflammation compared to the pain and/or exposure group and the voiding dysfunction and pain/exposure group and this finding was statistically significant: 47.6 vs 26.7 vs 36.7 %, $p=0.02$. Furthermore, pairwise testing showed that the median grade of inflammation was higher in the voiding dysfunction group compared to the other 2 groups: 2 (range 1–3) in the voiding dysfunction group, 1 (range 0–3) in the pain and/or exposure group, and 1 (0–3) voiding dysfunction plus pain and/or exposure group.

Moderate fibrosis was seen in 61 % of pathological specimens with no difference found between the three groups. Almost all subjects (89.2 %) demonstrated giant cell reaction with no differences between groups. Figure 1a shows excised midurethral mesh and vaginal tissue with the representative histological grading system.

## Discussion

The optimal implant into human tissue has been described as one that does not elicit a significant host-tissue reaction, is lightweight, maintains flexibility, and provides long-term support [10]. In 1997, Amid created a classification of biomaterials used in abdominal wall hernia repair according to the specific properties of each mesh including filament type, pore size, and weight. Of the four types of mesh in this classification system, polypropylene mesh, which is used in most midurethral slings, is classified as a type 1 mesh and contains many of the desirable properties listed above. The host response to polypropylene mesh has been described in human and animal models [15]; however, the response in the human vagina has not been well studied.

In our study, we found that the majority of vaginal mesh was removed for voiding dysfunction alone, with a large proportion also undergoing excision for both voiding dysfunction and pain and/or mesh exposure. The most common histopathological responses in all groups, including those with voiding dysfunction alone, were mild inflammation, moderate

**Table 3** Histological comparison between groups

| | Voiding dysfunction ($N=60$) | Pain/mesh exposure ($N=21$) | Voiding dysfunction and pain/mesh exposure ($N=49$) | $p$ value |
|---|---|---|---|---|
| Inflammation (%) | | | | 0.02 |
| None (0) | 0 | 15 | 6.1 | |
| Mild (1) | 42.9 | 56.7 | 55.1 | |
| Moderate (2) | 47.6 | 26.7 | 36.7 | |
| Marked (3) | 9.5 | 1.7 | 2.0 | |
| Fibrosis (%) | | | | 0.6 |
| None (0) | 0 | 0 | 2.0 | |
| Mild (1) | 23.8 | 25.0 | 22.5 | |
| Moderate (2) | 71.4 | 70.0 | 59.2 | |
| Marked (3) | 4.8 | 5.0 | 16.3 | |
| Giant cell reaction (%) | 90.5 | 86.7 | 89.2 | 0.7 |